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95 РОКІВ ПДТУ

Figure 2 – Microhardness distribution across the laser-hardened layer [1]

Accordingly, dry sliding pin-on-disc tests (Al_2O_3 counterbody, 10 N, 500 m) reveal that combination of bulk pre-HT and LST resulted in 3.94-times lower volume loss as compared to AR state while the friction coefficient lowered from ~0.65 to ~0.45. After LSR, the wear mode shifted from abrasive grooving and carbide pull-out (AR), to a thin protective oxide tribo-layer formation with gradual spalling and self-replenishes to minimize matrix damage (LSR). Here, the high RA content plays a dual role: (1) TRIP-assisted energy dissipation during sliding, delaying crack nucleation; (2) lubricious ɾ-phase reducing adhesion. Combined with carbon-rich martensite and nanostructure, this yields outstanding specific wear resistance. Applying LST to the pre-hardened, RA-enriched HT substrate outperforms laser-only treatment on AR material. This two-step protocol (standard bulk HT + final non-melting LST) requires no specific equipment beyond industrial fiber lasers. It delivers: – tool life extension in punching, blanking, and fine-blanking, – reduced downtime from chipping/galling, – sustainability via longer intervals between regrinding or replacement. The synergy of ultrafine martensite, high-volume metastable austenite, and strategic carbide scaffolding under laser-induced microalloying sets a new benchmark for severe-duty cold work applications.

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Reference

1. Chabak Y., Efremenko V., Barma Y., Petrišinec I., Efremenko B., Kromka F., Sili I., Kovbasiuk T. Enhancing Dry-Sliding Wear Performance of a Powder-Metallurgy-Processed “Metal Matrix–Carbide” Composite via Laser Surface Modification. Eng 2025, 6, 313. https://doi.org/10.3390/eng6110313.

MULTICOMPONENT MATRIX-CERAMICS COMPOSITE BY HYBRID ADDITIVE MANUFACTURING

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This study undertakes an evaluation of the microstructure, hardness, and dry-sliding wear performance characteristics exhibited by a novel multicomponent Fe-C-B-W-Mo-V-Cr-Ti carboboride/metal matrix composite material, which was fabricated by an innovative hybrid additive manufacturing that integrates spark plasma sintering (SPS), followed by laser surface melting (LM), and supplemented with post-heat treatment (HT), in comparison with its sand-cast multicomponent cast iron (MCCI) counterpart with a similar overall chemical composition. The SPS/LM specimens demonstrated the formation of a 1 mm thick porosity-free surface layer with a refined dual-composite structural architecture. This structure contained (Fig. 1): (i) an external framework composite microstructure of hard eutectic colonies, including Chinese-script (CS) colonies made up of fine $(W, Mo, Cr, V)_2(B, C)_5$ fibers embedded within an acicular martensitic

matrix, alongside ledeburite colonies featuring a $(Fe, Cr, W, Mo, V)_3(C, B)$ matrix that encapsulates martensite-filled capillary-like channels, all of which are integrated into a broader acicular martensitic matrix; (ii) an intricate internal composite microstructure characterized by the presence of additional (carbo)boride fibers situated within the martensitic matrix of the aforementioned CS colonies, complemented by equiaxed Ti,W-C-O-N inclusions.

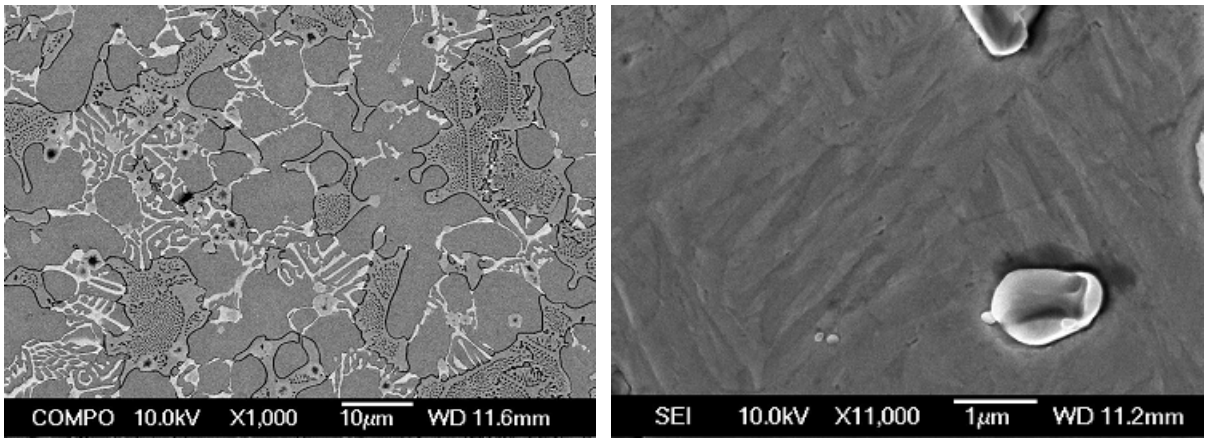

Figure 1 – Microstructure of the SPS/LM composite material: (a) total view, (b) martensitic matrix

The latter exhibit a gradient structure consisting of a central (Ti,W)-O-C-N rosette-shaped core enveloped by an outer (Ti, W)-carboboride shell. Although the overall morphological features and phase elemental compositions of the composite was largely consistent with those of sand-cast MCCI material, the SPS/LM exhibited a remarkable structural refinement of the matrix dendrites, carboboride inclusions, and eutectic colonies: they reduced in size by factors ranging from 2 to 25 times compared to the MCCI counterpart.

The heat treatment (holding at 1150 °C for 2 hours followed by oil quenching) induced the microstructural changes: an increase in carbon content within the matrix, a higher volume fraction of RS, elevated dislocation density, and redistribution of alloying elements, where Cr and W atoms diffused from the CS fibers and matrix dendrites into the $M_3(C,B)$ plates of the ledeburite, thereby enhancing their hardness and raising the overall composite hardness to 1006 HV.

Under the dry-sliding wear testing, the SPS/LM composite consistently demonstrated superior wear resistance in comparison to the MCCI: approximately 1.7 times higher in the as-fabricated state and 1.5 times higher following heat treatment. LM improved the wear resistance of the base SPS alloy by a factor of 1.6, with post-heat treatment providing an even higher enhancement, reaching a 3.2-fold increase overall. The wear resistance coefficients followed this sequence: as-cast MCCI < untreated SPS < SPS/LM < heat-treated MCCI (MCCI/HT) < SPS/LM/HT. Friction coefficients decreased in the order: MCCI > SPS/LM/HT > SPS/LM ≥ untreated SPS > MCCI/HT. Wear mechanisms in SPS/LM and SPS/LM/HT primarily involved low-cycle fatigue, with matrix microcracks and delamination, accompanied by abrasion manifesting as shallower grooving and surface oxidation. In contrast, the sand-cast MCCI degraded through lateral build-up formation and intense plastic deformation. Ultimately, the SPS/LM/HT hybrid process offers an outstanding balance of hardness and wear performance, establishing it as a highly promising candidate for demanding severe abrasive and wear-resistant applications.

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THE CONCEPT OF COST-EFFECTIVE ULTRAHIGH-STRENGTH LIGHTWEIGHT STEEL WITH SMART NANO-SIZED MICROSTRUCTURE

